

Chapter 5. Groundwater

5.1 Introduction

Kentucky's groundwater is an important source of drinking water for more than one million Kentuckians, as well as a source of water for industry and irrigation. An estimated 1,292,744 Kentuckians are served by 211 public water systems (PWSs) that rely on groundwater, in whole or part, as their source. An additional 447,154 rural Kentuckians not connected to public water systems rely on private wells, springs and other sources (e.g. cisterns) for their drinking water (Figure 5-1). Groundwater also contributes significant recharge to streams. Protection of this resource is crucial to Kentucky's economy, public health and the environment.

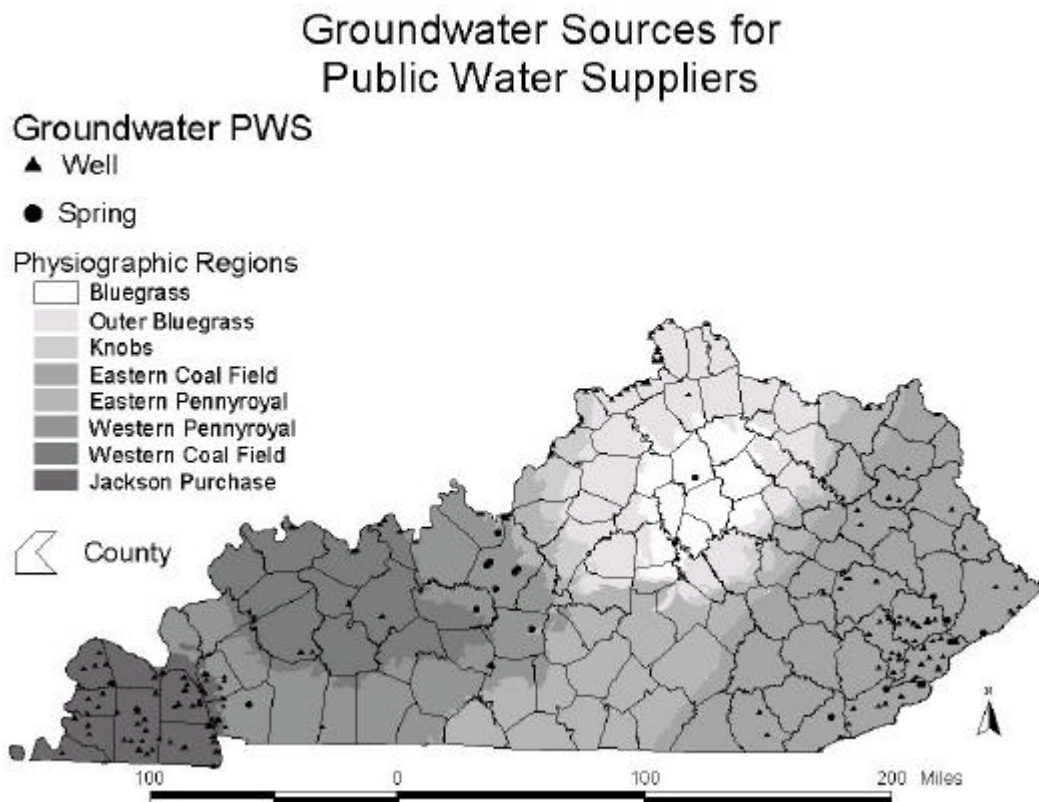
5.2 Availability and Use

Naturally occurring potable groundwater is found throughout Kentucky, although quantities available for use vary considerably, as controlled by regional geologic characteristics. Kentucky's groundwater resources occur in four aquifer types: (1) alluvial deposits in the Ohio and Mississippi river valleys; (2) karst aquifer systems of the Pennyroyal and Bluegrass regions; (3) unconsolidated sediments of the Jackson Purchase area; and (4) fractured bedrock aquifers of the Eastern and Western Coal Fields.

High-yielding wells constructed in alluvial deposits are typical of the Ohio and Mississippi river valleys that comprise Kentucky's northern and western borders. Wells in these valley aquifers are the most productive of any wells in the Commonwealth, producing adequate, high-quality water for domestic, public, industrial and agricultural use. Much of Kentucky's future drinking water needs will be met by these aquifers, as evidenced by recent moves to use them rather than surface-water sources.

Karst aquifers, developed in soluble rocks (e.g. limestone), are characterized by numerous shallow conduit-flow systems of generally limited extent. Approximately 50 percent of Kentucky is underlain by karst aquifers. The most extensive karst aquifers are in the Pennyroyal region of western Kentucky. Karst aquifers are present, but less well developed, in the Inner Bluegrass region. The availability of groundwater in karst areas is highly variable and generally supports public and domestic supplies. Locally, karst groundwater may support agriculture and industry.

Figure 5.1. Groundwater sources for public water suppliers in Kentucky.

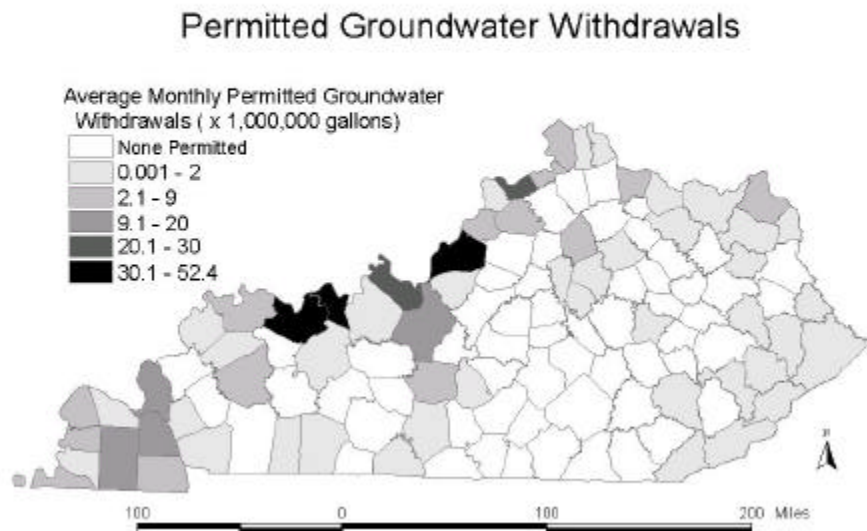


In the Western and Eastern Coal Field regions, wells in fractured sedimentary rocks generally provide sufficient water for domestic use and locally provide sufficient water for smaller public water systems. The unconsolidated sediments of the Jackson Purchase region are prolific aquifers, supporting widespread domestic, industrial and agricultural use, as well as public water systems.

In 2003, 35 percent of public water systems (PWSs) in Kentucky depended upon groundwater, in whole or part, as a source, withdrawing more than 70 million gallons per day total (Figure 5.2). The majority of groundwater use for PWSs is groundwater withdrawn from the alluvial deposits along the Ohio River and unconsolidated sediments in the Jackson Purchase. PWSs in eastern Kentucky are supplied by water wells and a number of PWSs in the Pennyroyal

and Bluegrass utilize natural springs. Households that depend upon private water wells for their drinking water are most numerous in eastern Kentucky and in the Jackson Purchase; these two regions account for about 75 percent of all new well construction in the state. Approximately 440,000 persons depend on groundwater from wells and springs to supply individual households (Table 5-1). This number of people on private sources (e.g. wells, springs) is decreasing as public

Figure 5.2. Permitted groundwater withdrawals in Kentucky.



water systems expand to serve areas previously unserved. Households that depend upon private water wells for their drinking water are most numerous in eastern Kentucky and in the Jackson Purchase; these two regions account for more than 65 percent of all new well construction in the state (Figure 5.3).

Table 5-1. Estimates of state population served by public water and private sources

	2003	% State Population	2000	% State Population	1990	% State Population
# Service Connections	980,676	N/A	958,150	N/A	900,217 ^a	N/A
Population Served	3,594,615 ^d	88.9%	3,512,049 ^b	86.89%	2,970,717 ^c	80.61%
Population not served by a Community PWS ^e	447,154	11.1%	529,720 ^d	13.11%	714,578	19.30%
Population on private wells	316,167 ^g	7.82%	374,547	9.27%	505,254	13.71%
Population on private springs and other sources	130,987 ^g	3.24%	155,173	3.84%	209,324	5.68%
Total	4,041,769 ^f	100.00	4,041,769 ^f	100.00	3,685,296	100.00

^a This is an estimated number of connections based on the population served in 1990.

^b The population served by Community Public Water Systems was estimated in 2000.

^c Number available from U.S. Census Bureau 1990.

^d Population served was calculated assuming an increase in population served proportional to an increase of 2.35% in the number of connections, as reported by PWSs.

^e Population Not Served by a Community PWS includes those who depend on private wells, springs, cisterns and hauled or bottled water. Subtracting the population served by PWSs from the total population of the state arrived at this number. Definitions: 1) "Community Public Water Systems" are public water systems serving an average of ≥ 25 people/day year-round or systems with ≥ 15 service connections; 2) "Service connections" are individual homes and businesses connected to Community Public Water Systems; 3) "Other sources" are springs, cisterns, and hauled water.

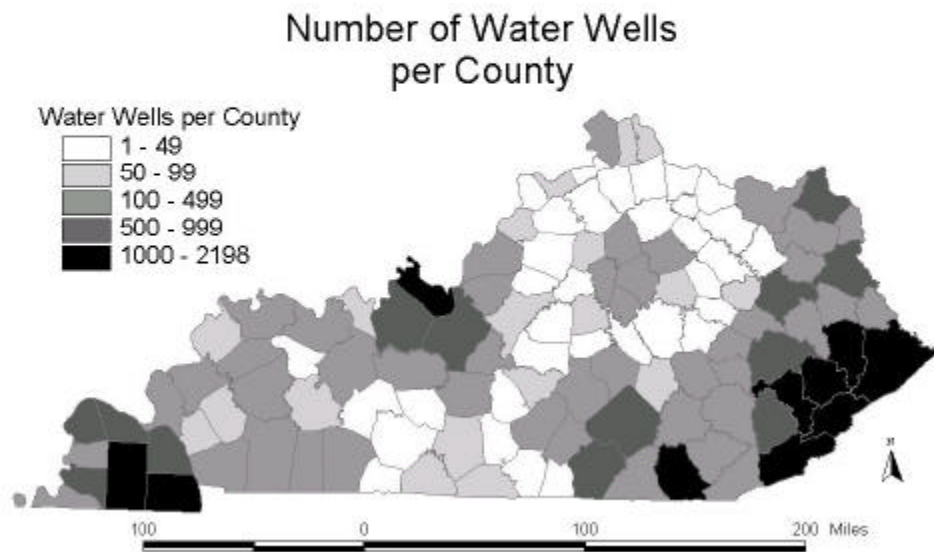
^f Number available from U.S. Census Bureau 2000. This number is assumed to have not changed significantly since 2000.

^g Numbers were calculated based on an assumed approximate constant ratio of the unserved population on private wells to the population on private springs and other sources.

5.3 Groundwater Quality

In Kentucky, the quality of groundwater used by households for private domestic supplies appears to be generally good, although there are regions of the state where specific problems exist. The principal, naturally occurring groundwater problems include pathogen infestation, elevated nitrates, high levels of iron and sulfur, and high levels of total dissolved solids (TDS) (“salty” or “hard” water). Of these contaminants, the presence of nitrates and pathogens in drinking water represent potentially serious health risks if regularly consumed above maximum contaminant levels (MCLs), especially by persons vulnerable to infection or other health impacts

Figure 5.3. Number of water wells per county in Kentucky.



(e.g. young children, the elderly, immune-compromised people). Pathogens, indicated by the presence of coliform bacteria, generally occur in wells from a lack of regular maintenance. Well disinfection is a simple process, but most well owners do not regularly conduct well disinfection. Pathogens are introduced to the well by other maintenance on the well or distribution system within the household. Pathogens may also be introduced to improperly constructed wells from local soils and may be impacted by septic systems or other on-site disposal. Improperly constructed wells

(e.g. insufficient casing, hand-dug wells) and shallow tile wells are more susceptible to pathogen infection than properly constructed wells. Normal pathogen response includes gastro-intestinal problems and flu-like symptoms.

Elevated nitrates (greater than 10 parts per million) do occur locally, principally in shallow wells in areas where sources of nitrate (e.g. fertilizer applications, manure storage and application, animal feedlots) are prevalent. Elevated nitrates are known to cause methemoglobinemia, or blue baby syndrome, in infants. Blue baby syndrome is a condition caused by the conversion of nitrate to nitrite in the blood, which affects the blood's ability to carry oxygen. Infants suffering from methemoglobinemia have skin that turns a blue-gray color, a condition known as cyanosis.

Elevated levels of iron and sulfur do not represent health risks, but do affect the aesthetic quality of water; water with relatively high levels of iron and sulfur have taste and odor issues, as well as staining of appliances, but are not particular health risks. Iron and sulfur are the most prevalent problems with well-water quality in Kentucky, as well as many other regions of the country.

Elevated TDS in wells occurs naturally in some areas and in other areas may be impacted by historic oil and gas drilling and injection activities. Elevated TDS is largely an aesthetic concern, making water “hard” and causing scaling in pipes and appliances. At higher levels, water may taste “salty” which at various levels is objectionable to some people.

5.3.1. Contamination Issues

Groundwater quality in Kentucky is generally good; water quality is directly related to land use, geology, groundwater sensitivity and well construction. Non-point source impacts on groundwater quality occur from nutrients and pesticides and result primarily from agricultural activities. Major sources of groundwater contamination in Kentucky are listed in Table 5-2.

Nitrates are a widespread concern, especially in shallow wells constructed in alluvial and coastal plain aquifers. Nitrates impact these aquifers largely because recharge in these areas is significantly rapid that attenuation of nitrates is not complete in the upper soil horizons. Agricultural activities, including fertilizer application, manure storage and application, and animal feeding operations are the principal sources of nitrates for these aquifers. Elevated nitrates have impacted a small number of PWSs relying on groundwater. In addition, preliminary data

Table 5-2. Major sources of groundwater contamination.

Contamination Source	Ten Highest Priority Sources (X)	Factors Considered in Selecting a Contaminant Source (See Below) (Use all that apply)	Contaminants (See Below) (Use all that apply)
<u>Agricultural Activities</u>			
Agriculture Chemical Facilities			
Animal Feedlots	X	I, III, V, VI, VII	B, E, J, K, L
Drainage Wells			
Fertilizer Applications	X	I, III, IV, V, VI, VII	E
Irrigation Practices			
Pesticides Applications	X	I, III, IV, VI, VII	A, B
On-farm Agricultural Mixing and Loading Procedures			
Land Application of Manure (unregulated)			
<u>Storage and Treatment Activities</u>			
Land Application			
Material Stockpiles			
Storage Tanks (above ground)			
Storage Tanks (underground)	X	I, III, IV, V, VI, VII	C, D, H
Surface Impoundment			
Waste Piles			
Waste Tailings			
<u>Disposal Activities</u>			
Shallow Injection Wells (Class V) – includes stormwater runoff from urban and agricultural land uses.	X	I, II, III, IV, V, VI, VII	A, B, C, D, E, F, G, H, J, L, M (Sediment)
Deep Injection Wells			
Landfills, including pre-law landfills	X	I, III, IV, V, VI, VII	A, B, C, D, E, F, G, H, I, J, K, L, M (Leachate Compounds)
Septic Systems	X	I, II, III, IV, V, VI, VII	A, B, C, D, E, F, G, H, J, K, L
<u>Other</u>			
Dry Cleaners	X	I, III, IV	C (TCE)
Hazardous Waste Generators			
Hazardous Waste Sites			
Industrial Facilities	X	I, III, IV, V, VII	A, B, C, D, E, F, G, H, I, J, K, L, M (TCE)
Material Transfer Operations			
Mining and Mine Drainage	X	I, III, IV, V, VI, VII	G, H, M (Sediment runoff, dewatering wells)
Oil and Gas wells/operations		III, IV, VI, VII	G, H
Pipelines and Sewer Lines			
Salt Storage and Road Salting			
Salt Water Intrusion			
Spills	X	I, II, III, IV, V, VII	A, B, C, D, E, F, G, H, I, J, K, L, M (TCE)
Transportation of Materials			
Various (e.g. drums wire-burners, battery crackers)			B, C, D, H,
Small-Scale Manufacturing and Repair Shops			
<u>Factors</u>		<u>Contaminants</u>	
I- Human Health and/or environmental risk (toxicity)		A- Inorganic Pesticides	
II- Size of the population at risk		B- Organic Pesticides	
III- Location of the Sources relative to drinking water sources		C- Halogenated compounds	
IV- Number and Size of contaminant source		D- Petroleum compounds	
V- Hydrogeologic Sensitivity		E- Nitrate	
VI- State Findings, other Findings		F- Fluoride	
VII- Best Professional Judgment		G- Salinity / Brine	
		H- Metals	
		I- Radionuclides	
		J- Bacteria	
		K- Protozoa	
		L- Viruses	
		M- Other (see narrative)	

indicate that shallow, private wells are more likely to have elevated levels of nitrates.

Pesticides are also a concern, principally in karst regions, the only areas of the state where pesticides are routinely detected in groundwater samples. Pesticides bypass soil attenuation processes in karst areas and contribute to elevated levels in karst groundwater systems. These aquifers, in turn, redistribute this pesticide-laden water to surface water systems in an efficient fashion, as groundwater and surface water in karst systems are in direct communication. Pesticides in groundwater have largely been a seasonal issue, but detections and significant concentrations are not limited to application season. Elevated levels of atrazine are most common. Elevated levels of atrazine in groundwater and surface water recently resulted in compliance problems for two PWSs in western Kentucky.

Urban sprawl and urban storm-water runoff also impact karst aquifers. Sprawl threatens some karst aquifers, particularly where new growth does not coincide, as is common, with extension of sewers. The additional hydrological loading resulting from concentrated use of septic systems exasperates collapse potentials, and the increased hydrologic, pathogen and nutrient loading commonly has dramatic effects on groundwater quality in karst basins. Improper storm-water injection in karst areas also impacts local karst groundwater quality.

High levels of naturally occurring iron and sulfur continue to impact private wells, producing aesthetic problems for well owners in many parts of the state, especially eastern Kentucky. The high levels of iron and sulfur commonly result from a lack of proper well maintenance, and in most circumstances, are preventable and treatable.

Bacteria occurrence remains common in wells, usually indicating potential sanitary problems. The occurrence of bacteria in well systems commonly results from a lack of proper well maintenance, and in most circumstances, is preventable and easily treatable.

Local contamination from landfills, USTs, Superfund and hazardous waste sites remains a concern as much for Kentucky as for other states. However, no widespread impacts or negative trends on water quality resulting from waste sites have occurred in Kentucky. The occurrence of MTBE and BTEX is largely limited to contaminated sites; occasional minor detections of BTEX and MTBE in urban karst springs result from storm-water runoff. Disruption of groundwater use of both private and public water supply wells because of contamination has occurred locally, but has been uncommon. There are currently 1489 sites with known or suspected groundwater contamination, including 1220 UST sites, 30 solid waste sites, 192 state and federal Superfund

sites and 47 hazardous waste sites with groundwater contamination (Table 5-3). The department is tracking contaminated groundwater sites and the condition of groundwater at these sites. Kentucky has recently developed a broad-based remediation program that applies to contaminated sites, including brownfields. This program should significantly reduce the number of contaminated sites over the next several years.

5.3.2. Ambient Groundwater Quality Monitoring

The Division of Water has collected and analyzed more than 2900 groundwater samples from more than 400 sites to characterize ambient groundwater conditions and nonpoint source impacts to groundwater (Figure 5.4). Sites are sampled from one to six times per year, based on aquifer type and monitoring goals. Water quality parameters evaluated include nutrients, major inorganic ions, metals, pesticides and volatile organic compounds, including MTBE. Analysis of groundwater for pathogens is a major logistical challenge. The division is beginning to address this gap in data.

A summary of the results of ambient groundwater monitoring for major parameters of concern in Kentucky is presented in Table 5-4. Water quality trends can be related to regional geology, land use, groundwater sensitivity (Figure 5.5) and well construction. Impacts on groundwater quality from human activities occur predominantly in the most sensitive (karst) areas and result primarily from agricultural activities. Persistent localized groundwater contamination from human activities occurs around older landfills, leaking underground storage tanks, poorly maintained septic systems and straight pipes, mining operations and drainage, and urban runoff. Less persistent, but still of concern locally, are spills and contamination from industrial facilities. Urban storm-water runoff is an increasing concern, particularly in karst areas where storm water is commonly managed via Class V Underground Injection Control wells.

Results. Specific groundwater quality standards have not been adopted in Kentucky; however, other applicable and appropriate standards are used to determine whether there have been impacts to groundwater. Generally, we assume the highest use of groundwater: that the groundwater is being consumed without any treatment, as hundreds of thousands of Kentuckians do consume groundwater in this fashion. Therefore, drinking water standards are generally used as a comparative standard for groundwater quality. Drinking water standards include maximum

Table 5-3. Groundwater contaminated sites summary, 2002 – 2003. Dates : 1-1-2002 to 12-31-2003 (Cumulative; subtracts sites that have been closed and includes new sites.)

Source Type	Number of Sites		Number of Sites with Confirmed Releases	Number of Sites with Groundwater Contamination	Contaminants	Source
<u>NPL</u>	19		19	19	PCBs, SVOCs, VOCs, Metals, Inorganics, Pesticides and Radionuclides	Division of Waste Management (DWM) Superfund Branch State Superfund Section
State Sites	1897		1217*	128**		
<u>CERCLIS</u>						
Non-UST Petroleum	949		908*	40-45**	Petroleum	
Old Landfills	22		22	22		DWM – Solid Waste Branch
<u>UST</u>	4,534		2,598	1,220	BTEX, PAH, Lead	DWM - UST Branch
<u>RCRA</u> Corrective Action	89	RCRA-D 32	30	30	Organic Compounds	DWM - Solid Waste Branch
		RCRA-C 59	53**	41	Pesticides, Cyanide, PCBs, VOCs, ABNs, PAHs, Metals, and Radionuclides	DWM – Hazardous Waste Branch
<u>DOD/DOE</u>	6		6	6		
<u>UIC</u>	Total 4365	Class I	N/A	N/A	Varied	EPA
		Class II 3066				
		Class V 6771				

Source Type

NPL - National Priority List

DOD - Department Of Defense

DOE - Department Of Energy

CERCLIS - Comprehensive Environmental Response, Compensation, and Liability Information System

RCRA - Resource Conservation and Recovery Act

UIC - Underground Injection Control

UST - Underground Storage Tank

* - This number is a best estimate; a new tracking system is being implemented and compliance with tracking protocols is not 100%.

** - This number is an approximation; not all sites have been verified.

*** - This number is estimated. Determining what constitutes a confirmed release for soils can vary based on the standard applied (e.g., U.S. EPA Region IX screening values, ambient background conditions, etc.).

Contaminants

PCB - Polychlorinated Biphenyl

SVOC - Semi Volatile Organic Compound

BTEX - Benzene, Toluene, Ethylene, and Xylene

PAH - Poly Aromatic Hydrocarbons

VOC - Volatile Organic Compound

ABN - Acid Base Neutral

contaminant levels (MCLs), secondary (aesthetic) standards (SMCLs), both promulgated for the drinking water program that regulates public water systems (PWSs). In addition, for elements or compounds that do not have an MCL or SMCL, a health advisory level (HAL) is used as a standard. Some impacts, such as nonpoint source impacts, to groundwater may be significant but well below any health or aesthetic concerns. It is appropriate to use reference groundwater conditions as a comparative standard for assessing these types of impacts.

Results: Inorganics. Fluoride is common in much of Kentucky as the mineral fluorite, and its presence in groundwater is also common; 95 percent of 571 samples collected over the reporting period had detections on fluoride. Only four samples exceeded the MCL for fluoride. The MCL is based on getting too much of a good thing. Fluoride is important in the development of health teeth and bones, but too much of this important mineral can cause fluoridosis of teeth and bones.

Results: Nutrients. As noted before, nitrate is naturally occurring in groundwater, but normally at low levels. Nitrate in elevated concentrations (>10 mg/L) in drinking water can cause health problems, specifically methemoglobinemia. Eighty-nine percent of samples collected detected nitrate; only four samples exceeded the MCL. However, we believe that planned research focused on shallow wells in agricultural areas will indicate a more widespread problem with nitrate in shallow groundwater.

Results: Metals. Arsenic was detected in approximately 18 percent of ambient samples collected and was detected at levels above the MCL (0.010 mg/L) in six (6) wells in the eastern Kentucky Coal Field and one well in the Ohio River alluvium. Arsenic is naturally occurring, and its occurrence may be related to iron-reducing bacteria in these wells.

Lead, a metal found in natural deposits, is commonly used in household plumbing materials and water service lines. Lead is not commonly detected in most groundwater, but is sometimes detected in samples as a result of leaching of lead from plumbing materials and service lines. Lead was detected in 18 percent of 579 samples collected, but exceeded the action level for lead in only seven (7) samples. Nevertheless, lead presents a significant health risk at even mildly elevated levels and needs to be addressed in each of the sources where it was detected.

Figure 5.4. Kentucky ambient groundwater monitoring network.

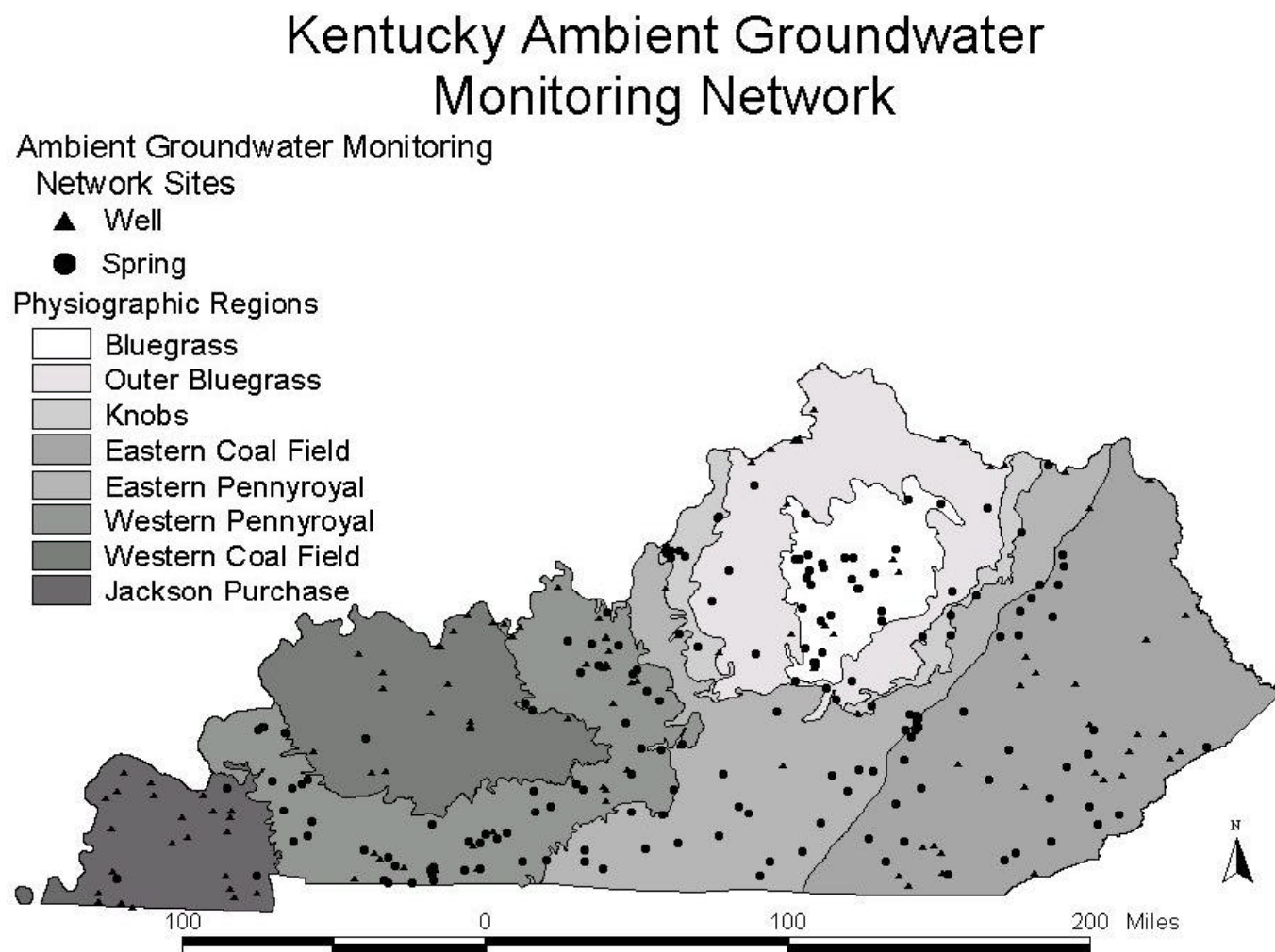
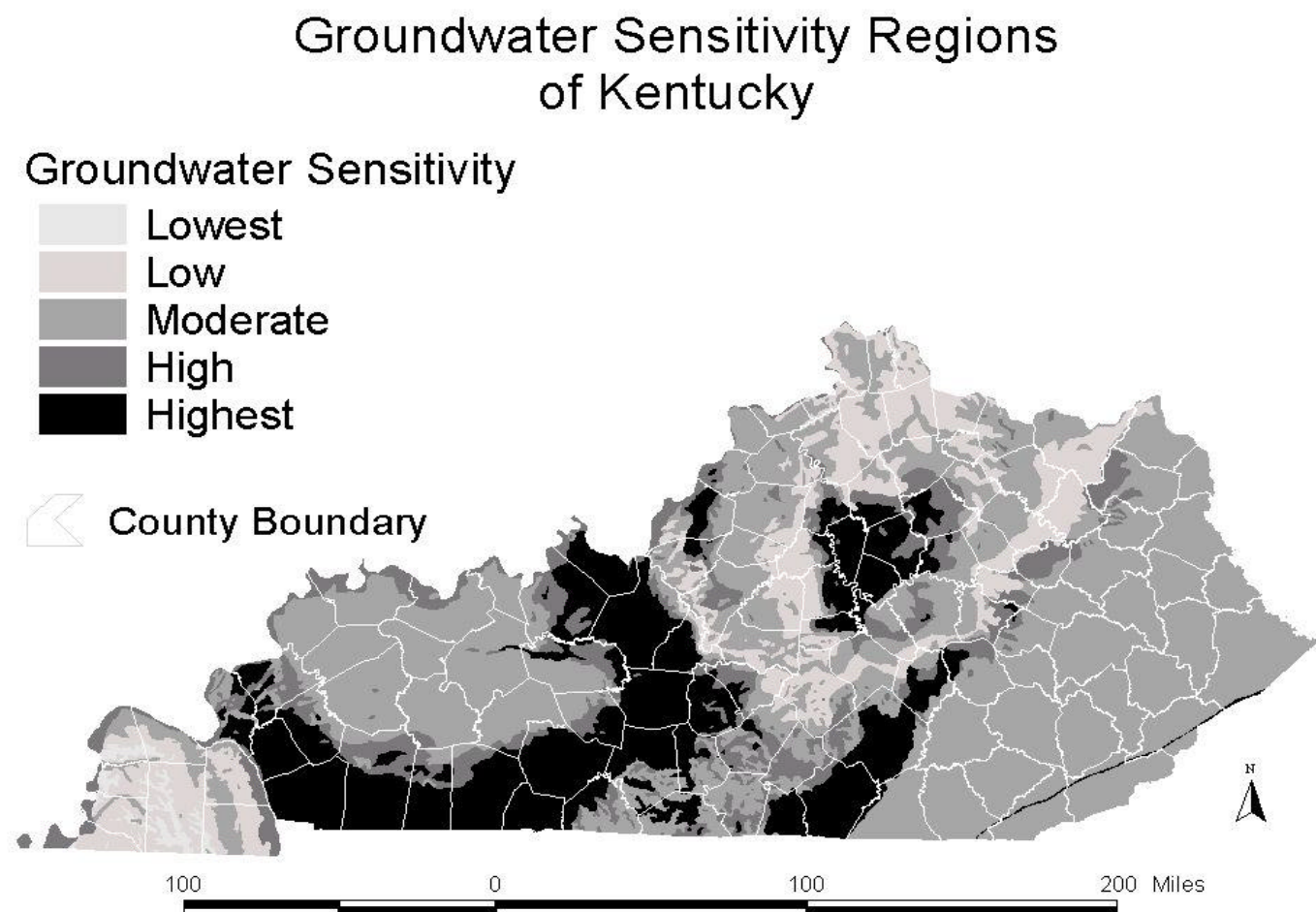


Table 5-4. Summary of ambient groundwater monitoring results.

SUITE	CONSTITUENT	MCL (mg/L)	NUMBER OF SITES	SITES WITH DETECTS	SITES w/ DETECTS < 1/4 MCL	SITES w/ DETECTS ~ 1/4 MCL	SITES w/ DETECTS > MCL	NUMBER OF SAMPLES	NON-DETECTS	DETECTS < 1/2 MCL	DETECTS >= 1/2 MCL	DETECTS > MCL
OTHER	Fluoride	4	139	137	136	5	4	571	27	539	5	4
	Nitrate (as N)	10	139	126	118	28	6	571	65	429	77	9
	Nitrite (as N)	1	136	71	71	0	0	475	327	148	0	0
RCRA METALS	Arsenic	0.010	139	57	52	7	4	579	474	95	10	7
	Barium	2	139	139	139	0	0	579	0	579	0	0
	Cadmium	0.005	139	7	6	1	0	579	566	12	1	0
	Chromium	0.1	139	85	85	0	0	579	337	242	0	0
	Copper	1.0	139	131	131	0	0	579	158	421	0	0
	Iron	0.3	139	133	81	105	87	579	65	213	301	220
	Lead	0.015	139	47	40	12	6	579	500	66	13	7
	Manganese	0.05	139	136	89	83	65	579	54	287	238	162
	Mercury	0.002	139	3	3	0	0	579	576	3	0	0
	Nickel	0.1	139	72	72	0	0	579	412	167	0	0
	Selenium	0.05	139	52	52	0	0	579	483	96	0	0
	Silver	0.1	139	9	8	1	1	579	570	8	1	1
	Zinc	5	139	129	128	1	1	579	196	382	1	1
PCB	Aroclor 1016	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1221	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1232	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1242	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1248	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1254	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1260	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1262	0.0005	139	0	0	0	0	567	567	0	0	0
	Aroclor 1268	0.0005	139	0	0	0	0	567	567	0	0	0
PESTICIDES	Acetochlor	0.055	139	6	6	0	0	575	564	11	0	0
	Alachlor	0.002	139	8	8	0	0	575	557	18	0	0
	Atrazine	0.003	139	56	55	7	3	575	384	183	8	3
	Atrazine desethyl	0.003	139	46	46	0	0	575	406	169	0	0
	Cyanazine	0.001	139	0	0	0	0	575	575	0	0	0
	Metolachlor	0.1	139	31	31	0	0	575	493	82	0	0
	Simazine	0.004	139	33	32	2	0	575	475	98	2	0
SOC	Anthracene	0.830	94	1	1	0	0	135	134	1	0	0
	Benzo(a)anthracene	0.000034	94	3	0	3	0	135	132	0	3	0
	Benzo(a)pyrene	0.0002	94	4	4	0	0	136	131	5	0	0
	Fluorene	0.110	94	2	2	0	0	135	133	2	0	0
	Naphthalene	0.1	137	1	1	0	0	547	546	1	0	0
VOC	Benzene	0.005	137	1	1	0	0	547	546	1	0	0
	Chlorobenzene	0.017	137	0	0	0	0	547	547	0	0	0
	Methylene chloride	0.005	137	2	1	1	1	547	545	1	1	1
	Ethylbenzene	0.7	137	0	0	0	0	547	547	0	0	0
	MTBE	0.05	137	4	4	0	0	547	540	7	0	0
	Tetrachloroethane (1,1,1,2-)	0.07	137	0	0	0	0	547	547	0	0	0
	Tetrachloroethene ³	0.010	137	10	10	0	0	547	506	41	0	0
	Toluene	1	137	9	9	0	0	547	538	9	0	0
	Trichloroethane (1,1,1-)	0.2	137	3	3	0	0	547	541	6	0	0
	Trichloroethene	0.002	137	7	5	3	1	547	529	9	9	7
	Vinyl chloride	0.002	137	0	0	0	0	547	547	0	0	0
	Xylene (1,2-)	10	137	0	0	0	0	547	547	0	0	0
	Xylene (1,3- & 1,4-)	10	137	2	2	0	0	547	545	2	0	0

Figure 5.5. Groundwater sensitivity regions of Kentucky.



Similarly to lead, both silver and zinc are uncommon in their occurrence in groundwater, especially at elevated levels. However, zinc and silver are sometimes detected in samples as a result of leaching of silver and zinc from plumbing materials and service lines. Of 579 samples analyzed for zinc, 66 percent of the samples detected some zinc, but only one (1) sample exceeded the secondary MCL, an aesthetic-based standard. Of the 579 samples analyzed for silver only eight (8) samples had any detections of silver, and only one (1) sample exceeded the SMCL. Most likely, these higher concentrations originated not from groundwater, but probably as a result of leaching of zinc and silver from plumbing materials and service lines. As noted previously, the occurrence of significant concentrations of iron and manganese is widespread. Of 579 samples, the majority had detections for iron and manganese, 38 percent of samples exceeded the aesthetic standard for iron and 28 percent exceeded the aesthetic standard for manganese.

Results: Pesticides and PCBs. Polychlorinated bi-phenyls (PCBs) were not detected in any of the 567 samples analyzed for these potent carcinogens. Some of the more commonly used herbicides were detected in samples, the most common being atrazine, with lesser occurrences of alachlor, metolachlor and simazine. Generally, these pesticides occur only in karst springs and do not exceed established health-based standards. Atrazine does appear to be more persistent in groundwater, occurring in 33 percent of 575 samples analyzed. Only three (3) samples exceeded the MCL for atrazine. However, the persistence of atrazine and its impact on some PWSs in Kentucky is raising concerns about its use. Efforts to monitor and assess the impact of atrazine on water quality and use of alternate herbicides are increasing in some areas.

Results: SOC. Semi-volatile organic compounds do not occur naturally in groundwater and are otherwise uncommon in their occurrence in ambient groundwater monitoring. Minor detections of several poly-aromatic hydrocarbons have occurred over the reporting period. The source for these anthropogenic contaminants is principally fuels, such as diesel fuel and gasoline. Although the occurrences of these contaminants are not at levels that exceed standards, their presence does suggest impacts from point sources (e.g. USTs) and nonpoint sources (e.g. storm water runoff).

Results: VOCs. The occurrence of volatile organic compounds always indicates anthropogenic impacts on groundwater. With the exception of trichlorethene (TCE), there were no significant

occurrences of VOCs in any of the ambient monitoring samples. The TCE, a solvent/degreaser, was detected at levels exceeding the MCLs at Humane Spring in Mercer County. This site is down gradient of a RCRA corrective action facility where TCE contamination is confirmed. The widespread presence of tetrachlorethylene (PCE) in minor amounts is a concern. This solvent is widely used in dry cleaning and as a metal degreaser and is occurring most commonly in urban springs. The occurrence of PCE in a PWS well in the Ohio River alluvial aquifer will be investigated.

5.3.3 Groundwater Quality and Public Water Systems

The Division of Water has collected and analyzed untreated groundwater samples at numerous public water systems (PWSs) to characterize groundwater conditions, including point source and nonpoint source impacts to groundwater at PWSs. This monitoring effort supports both the ambient groundwater monitoring program and the wellhead protection program, providing public water systems valuable information about the quality of their water supplies. A summary of the results of ambient groundwater monitoring for major parameters of concern in Kentucky is presented in Table 5-5. Groundwater quality at PWSs has been exceptional, which is critical to most PWSs that rely on groundwater; the majority of these systems do not treat their source water other than disinfection.

Table 5-6 illustrates the corresponding data for finished water (water distributed) at PWSs using groundwater as a source, either in whole or part. Fifteen (15) PWSs had 48 detections of various volatile organic compounds (VOCs), including P-dichlorobenzene, TCE, PCE, ethylbenzene and xylenes. Two (2) PWSs had detections of VOCs that exceeded the maximum contaminant levels. TCE occurred at one PWS that has had a historic problem with TCE and treats the water using air-scrubbing towers. Another PWS with TCE detections uses a groundwater source that is under the direct influence of surface water and has evidently been impacted by local runoff. Pthalates and methylene chloride were detected in a number of samples; however, these are considered to be lab and sampling contaminants and not contaminants occurring in the source. These water systems should be conducting or have completed increased monitoring for those contaminants. Thirty-two (32) PWSs had 83 detections of various semi-volatile organic compounds (SOCs), including 2-4 D, atrazine, alachlor, dalapon, diquat, simazine, ethylene di-bromide, dinosab, lindane, toxaphene, diquat, silvex (all

pesticides/herbicides) and benzo-A-pyrene. The herbicides were detected in minor amounts below the MCL and these PWSs were located in karst areas where the groundwater is under the direct influence of surface water, as well as being areas of dense agricultural (row cropping) activity, or the PWS had only a partial groundwater source and the contaminants were being extracted from surface water. None of these detections of SOC's exceeded applicable MCLs.

These PWSs should be conducting or have completed increased monitoring for those contaminants. Seven (7) PWSs had detections of inorganic compounds, including mercury, barium and cyanide, which exceeded MCLs. The three mercury detections above MCLs are being investigated; the occurrence of mercury in groundwater is rare. Both barium and cyanide are naturally occurring. Cyanide is normally oxidized by disinfection. Natural levels of barium can be physically removed by filtration if persistent. These PWSs should be conducting or have completed increased monitoring for those contaminants.

5.3.4. Monitoring Resource Issues

Although Kentucky is among the nation's leaders in coordinating its groundwater activities through its Interagency Technical Advisory Committee, additional resources are necessary to improve efforts to characterize Kentucky's groundwater. Routine monitoring should expand to better capture regional and temporal trends and conduct additional aquifer characterization for pathogens, pharmaceutically active compounds and other emerging pollutants. In addition, Kentucky needs to expand mapping of some aquifers to better assess aquifer quantity. Kentucky has recently invested significant resources to implement new technologies and consolidate data management. Kentucky also needs to expand groundwater education and public outreach.

Table 5-5. Summary of ambient groundwater monitoring results at PWS sites.

SUITE	CONSTITUENT	MCL (mg/L)	NUMBER OF SITES	SITES WITH DETECTS	SITES w/ DETECTS < ½ MCL	SITES w/ DETECTS ≥ ½ MCL	SITES w/ DETECTS > MCL	NUMBER OF SAMPLES	NON-DETECTS	DETECTS < ½ MCL	DETECTS ≥ ½ MCL	DETECTS > MCL
OTHER	Fluoride	4	27	27	27	1	1	119	5	113	1	1
	Nitrate (as N)	10	27	27	25	8	1	119	8	86	25	1
	Nitrite (as N)	1	27	20	20	0	0	99	59	40	0	0
RCRA METALS	Arsenic	0.010	27	13	12	2	0	123	102	19	2	0
	Barium	2	27	27	27	0	0	123	0	123	0	0
	Cadmium	0.005	27	1	1	0	0	123	122	1	0	0
	Chromium	0.1	27	12	12	0	0	123	72	51	0	0
	Copper	1.0	27	27	27	0	0	123	25	98	0	0
	Iron	0.3	27	25	18	18	16	123	22	49	52	38
	Lead	0.015	27	10	9	2	2	123	104	17	2	2
	Manganese	0.05	27	27	21	14	10	123	10	73	40	21
	Mercury	0.002	27	1	1	0	0	123	122	1	0	0
	Nickel	0.1	27	18	18	0	0	123	89	34	0	0
	Selenium	0.05	27	15	15	0	0	123	96	27	0	0
	Silver	0.1	27	3	2	1	1	123	120	2	1	1
	Zinc	5	27	24	24	0	0	123	51	72	0	0
PCB	Aroclor 1016	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1221	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1232	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1242	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1248	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1254	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1260	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1262	0.0005	27	0	0	0	0	121	121	0	0	0
	Aroclor 1268	0.0005	27	0	0	0	0	121	121	0	0	0
PESTICIDES	Acetochlor	0.055	27	0	0	0	0	121	121	0	0	0
	Alachlor	0.002	27	2	2	0	0	121	118	3	0	0
	Atrazine	0.003	27	11	11	2	0	121	70	48	3	0
	Atrazine desethyl	0.003	27	9	9	0	0	121	71	50	0	0
	Cyanazine	0.001	27	0	0	0	0	121	121	0	0	0
	Metolachlor	0.1	27	7	7	0	0	121	104	17	0	0
SOC	Simazine	0.004	27	7	7	0	0	121	89	32	0	0
	Anthracene	0.830	21	0	0	0	0	28	28	0	0	0
	Benzo(a)anthracene	0.000034	21	0	0	0	0	28	28	0	0	0
	Benzo(a)pyrene	0.0002	21	0	0	0	0	28	28	0	0	0
	Fluorene	0.110	21	1	1	0	0	28	27	1	0	0
	Naphthalene	0.1	27	0	0	0	0	118	118	0	0	0
VOC	Benzene	0.005	27	0	0	0	0	118	118	0	0	0
	Chlorobenzene	0.017	27	0	0	0	0	118	118	0	0	0
	Methylene chloride	0.005	27	1	1	0	0	118	117	1	0	0
	Ethylbenzene	0.7	27	0	0	0	0	118	118	0	0	0
	MTBE	0.05	27	2	2	0	0	118	114	4	0	0
	Tetrachloroethane (1,1,1,2-)	0.07	27	0	0	0	0	118	118	0	0	0
	Tetrachloroethene	0.010	27	5	5	0	0	118	101	17	0	0
	Toluene	1	27	2	2	0	0	118	116	2	0	0
	Trichloroethane (1,1,1-)	0.2	27	1	1	0	0	118	116	2	0	0
	Trichloroethene	0.002	27	2	2	0	0	118	116	2	0	0
	Vinyl chloride	0.002	27	0	0	0	0	118	118	0	0	0
	Xylene (1,2-)	10	27	0	0	0	0	118	118	0	0	0
	Xylene (1,3- & 1,4-)	10	27	0	0	0	0	118	118	0	0	0

Table 5-6. Finished Drinking Water Data at PWSs for Groundwater Systems

Finished Drinking Water Data from Groundwater Sources and Groundwater Sources Under the Direct Influence							
For Period of 1-1-02 to 12-31-03							
# of Sites	Parameter Group	Total # of Analyses	# of Non-detects < MDL	# of Detects >MDL to < MCL	Less than ½ MCL <=5	5 to <=10	Greater than the MCL
137	VOC	6991	6937	48	-----	-----	4
111	SOC	5738	5646	83	-----	-----	0
138	IOC	2921	2512	330	-----	-----	14
221	NO ₃	634	137	-----	412	85	0

5.4 Groundwater Protection Programs

Kentucky has established or is maintaining many programs that protect the Commonwealth's groundwater resources (Table 5-7). Three programs are highlighted in the following paragraphs.

Ambient Groundwater Monitoring Network: Since 1995, the DOW has collected more than 2900 groundwater samples at greater than 400 sites as part of the state's ambient groundwater monitoring program aimed at characterizing ambient groundwater conditions and non-point source impacts to groundwater. Monitoring sites include public and private water supplies, unregulated public access springs (i.e., "roadside springs") and unused springs. Approximately 70 sites are sampled from one to six times per year, depending on the type of aquifer. The Division of Water analysis these samples for a number of water quality parameters, including nutrients, major inorganic ions, metals, volatile organic compounds and semi-volatile organic compounds, including pesticides. Each year the Division of Water also collects approximately 120 samples on a watershed basis as part of an ongoing watershed initiative Section 319(h) cooperative effort. In addition, the DOW conducts quarterly groundwater monitoring at four sites under an agreement with the Division of Pesticide Regulation (DOPR) as part of DOPR's FIFRA grant work plan. The ambient monitoring program supports the Groundwater Protection Plan and Wellhead Protection programs by providing a resource-quality tracking measure and providing raw water data to PWSs using groundwater. In addition, the solid waste, hazardous waste, UST and Superfund programs all rely on the ambient network to characterize ambient conditions and identify potential problems.

Table 5-7. Groundwater Protection Programs^{a,b}

Programs or Activities	Implementation Status	Responsible State Agency
Active SARA Title III Program	✓ Continuing Efforts	Department for Environmental Protection Commissioner's Office
Ambient Groundwater Monitoring System	✓ Continuing Efforts	Division of Water
<i>Aquifer Vulnerability Assessment</i>	N/A	N/A
Aquifer Mapping	✓ Ongoing	Kentucky Geological Survey/Division of Water
Aquifer Characterization	✓ Ongoing	Kentucky Geological Survey/Division of Water
Comprehensive Data Management System	✓ Established	Division of Water
<i>EPA-endorsed Core Comprehensive State Groundwater Protection Program (CSGWPP)</i>	N/A	N/A
Groundwater Discharge Permits	✓ Continuing Efforts	Division of Water
Groundwater Best Management Practices	✓ Established	Division of Conservation
Groundwater Legislation	✓ Implemented	Division of Water/Kentucky Geological Survey
<i>Groundwater Classification</i>	N/A	N/A
Groundwater Protection Program	✓ Established	Division of Water
Groundwater Quality Standards	✓ Developing	Division of Water
Groundwater Sensitivity Mapping	✓ Complete	Division of Water
Interagency Coordination for Groundwater Protection Initiatives	✓ Established	Interagency Technical Advisory Committee
Non-Point Source Controls	✓ Established	Division of Water
Pesticides State Management Plans	✓ Developing	Division of Pesticides
Pollution Prevention Program	✓ Implementing	Division of Water
Resource Conservation and Recovery Act (RCRA) Primacy	✓ Established	Division of Waste Management
Source Water Assessment Program	✓ Continuing Efforts	Division of Water
State Superfund	✓ Established	Division of Waste Management
State RCRA Program Incorporating more Stringent Requirements than RCRA Primacy	N/A	N/A
State Septic System Regulations	✓ Established	Cabinet of Health Services
Underground Storage Tank Installation Requirements	✓ Established	Division of Waste Management
Underground Storage Tank Remediation Fund	✓ Established	PSTEAF
Underground Injection Control Program	✓ Fully Established	EPA Region IV
Table 5-7. Groundwater Protection Programs ^{a,b} .		
Vulnerability Assessment for Drinking Water/Wellhead Protection	✓ Completed	Division of Water
Well Abandonment Regulations	✓ Continuing Efforts	Division of Water
Wellhead Protection Program (EPA-approved)	✓ Established	Division of Water
Well Installation Regulations	✓ Continuing Efforts	Division of Water

^aItalicized programs are N/A (Not Applicable) at this time^bBold-faced programs are elaborated on the preceding pages

Groundwater Protection Plan Program: Kentucky's Groundwater Protection Plan regulation requires that entities conducting activities that have the potential to pollute groundwater develop and implement a groundwater protection plan. The plan includes pollution prevention activities such as preventive maintenance and best management practices; spill response plans, record keeping, training and regular inspections to ensure that the protective practices are in place and functioning properly. Kentucky's Agriculture Water Quality BMPs help prevent pollution of the waters of the Commonwealth.

Wellhead Protection Program: Kentucky's Wellhead Protection program requires that PWSs that rely on groundwater develop a wellhead protection (WHP) plan for their source water. A WHP plan is designed to delineate the recharge area of the well(s) or spring(s), identify the potential contaminant sources in the recharge area and implement groundwater protection strategies for these areas. Kentucky's WHP program is a fundamental part of its Source Water Assessment Program (SWAP), as required by the 1996 Amendments to the Safe Drinking Water Act. Kentucky has been a national leader in source water protection. Kentucky was the first state in the nation to have its SWAP approved by EPA.